ORIGINAL RESEARCH

Forecasting Medical Work at Mass-Gathering Events: Predictive Model Versus Retrospective Review

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Abbreviations:
PPR = patient presentation rate/1,000 spectators
THR = transport to hospital rate
TTHR = number of patients transported to a hospital/1,000 attendees

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Abstract

Introduction: Mass-gathering events are dynamic and challenge traditional medical management systems. To improve the system for the provision of first aid at mass-gathering events, an evaluation of two models that assist in forecasting the number of patients presenting for first-aid services was conducted.

Method: A prospective evaluation of a recurrent, mass-gathering event was undertaken comparing predicted patient presentations and ambulance transfers generated by a predictive model developed by Arbon *et al* and a retrospective review of seven years of historical, event data as described by Zeitz *et al*.

Results: Patient presentation rate (per 1,000 patrons) for this event was 1.6 and the transport to hospital rate (per 1,000 patrons) was 0.07. The retrospective review closely predicted the actual overall attendance. Both methods forecast the number of patients presenting on a daily basis. The prediction proved to be more accurate, on a day-by-day basis, using the Zeitz method.

Conclusion: The Arbon method is particularly useful for events where there is no or limited information about previous medical work. Retrospective review of data generated from specific events (Zeitz method) considers the unique and individual variability that can occur from event to event and is more accurate at predicting patient presentations when the data are available.

Both methods have the potential to be used more frequently to adequately and efficiently plan for the resources required for specific events.

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Introduction

The provision of emergency medical care in the mass-gathering setting traditionally has received minimal research attention.[1] Generally, research has focused on clinical care or analysis of a single event to assist in the provision of appropriately qualified personnel. In an attempt to improve the quality of the provision of first aid in the prehospital setting at mass-gathering events, this paper presents an evaluation of two methods that forecast the number of patient presentations at mass gatherings.

Contemporary Australian lifestyle is reflected in the large numbers of public and community events that are held across the continent. These range from school fetes and sporting competitions to international events such as the Formula One Grand Prix. Large public events are referred to as "mass gatherings".[2] Mass-gathering events in Australia with attendances >25,000 have been quantified for a 12-month period at 201 events with a combined spectator audience of 12 million people.[3]

Resource allocation to these events generally is based on experience and historical knowledge of events retained by individuals. Medical resource allocation traditionally has lacked substantive evidence to support decisions regarding appropriate staffing levels.[4–6] There is a need to make resource

Event Day		Arbon Method	Zeitz Method			Acutal Numbers of Presentations
			14–20ºC	>20ºC	<14ºC	
1st Friday	Treated	142	110	146	74	115
	Transported	3	4	4	4	4
1st Saturday	Treated	158	136	172	100	133
	Transported	3	3	3	3	11
Sunday	Treated	149	110	146	74	138
	Transported	3	1	1	1	6
Monday	Treated	138	97	97	97	128
	Transported	3	2	2	2	3
Tuesday	Treated	135	70	106	34	75
	Transported	3	2	2	2	3
Wednesday	Treated	150	162	162	162	147
	Transported	3	3	3	3	7
Thursday	Treated	143	122	158	86	170
	Transported	3	2	2	2	4
2nd Friday	Treated	146	117	153	81	63
	Transported	3	2	2	2	4
2nd Saturday	Treated	155	133	169	97	80
	Transported	3	3	3	3	5
9-Day Total	Treated	1,316	1,057	1,309	805	1,028
	Transported	27	22	22	22	47

Table 1—Number of patient presentation predictions for each method calculated prior to the 2002 Royal Adelaide Show. The Zeitz method provided different results, dependent on the maximal daily forecast temperature (˚C). The forecast temperature band for each day is in bold print. The actual recorded number of presentations and transports to a hospital are in the last column.

allocation at mass-gathering events more closely mirror actual needs rather than educated guesses.[2]

The St John Ambulance Australia Operations Branch has been involved in a number of studies reviewing medical work at mass-gathering events. In 1999, a model was developed by Arbon, Bridgewater, and Smith, predicting patient presentations at mass-gathering events based on an analysis of medical work at national major events during a 12-month period.[3] The Arbon *et al* predictive model uses estimated crowd size and event profiling to predict medical work.[3] The event profiling included: (1) the mobility of the crowd; (2) daily average humidity; (3) if there is a defined boundary to the venue; (4) if the event involves sport; (5) if the event occurs during the day or night; and (6) if it is held indoors or outdoors. The model, as described by Arbon *et al,* then calculates a predicted number of patient presentations and the number of patients that can be expected to require transfer to a hospital.[3]

In South Australia, in 2002, Zeitz *et al* undertook a longitudinal study to review the predictors of patient presentations at an annual agricultural and horticultural show.[4] The St John Ambulance Australia Operations Branch has maintained detailed records of patient presentations at the annual Royal Adelaide Show since 1995. Data available from this review included crowd size, number of patient presentations, weather, and the number of patients transferred to hospitals by ambulances (1996–2001). The inferences derived from seven years of data indicated that the significant factors predicting medical workload for this particular event could be estimated from the daily maximum temperature, crowd size, and day of the week (suggesting different crowd demographics on certain days, e.g., half-price admission days).

The current study was undertaken in order to compare the relative merits of different methods for predicting patient presentations at mass-gathering events. The objective was to determine if historical data from a recurring event enables a more accurate prediction of medical workload. This is important particularly in the context of a number of mass-gathering events that either are recurrent or have similar demographics to previously staged events, thus addressing the importance of gathering historical data.

Trained first-aid workers who are qualified members of the St John Ambulance Australia Operations Branch provide the medical services at the Royal Adelaide Show. The framework of service provision has remained the same for the past seven years. Members have a varied level of qualification ranging from a Senior First Aid Certificate to Advanced Resuscitation certification including automatic external defibrillation. Qualified paramedics and/or registered nurses, who are St John members, support these first-aid workers at the event. The service is managed from a central first-aid room supported by a St John communication team and a small first-aid outpost. Both first-aid rooms are staffed by St John members with the remainder of members used for an on-site transport service and multiple foot patrols. Research previously had been undertak-

Event Day	Actual	Predicted based on historical data
1st Friday	59,785	59,477
1st Saturday	103,870	93,372
Sunday	82,734	74,617
Monday	56,250	50,736
Tuesday	36,365	44,168
Wednesday	70,963	77,287
Thursday	65,455	62,404
2nd Friday	62,692	67,193
2nd Saturday	84,120	87,371
Total	**622,234**	**616,625**

Table 2—Actual attendance by day at 2002 event compared with predications based on historical attendance figures for the seven previous years of the event

Actual Casualties	Predictive Model	Retrospective Review
115	142	110
133	158	136
138	149	146
128	138	97
75	135	70
147	150	162
170	143	158
63	146	117
80	155	133
1,028	1,316	1,129

Table 3—Daily patient presentation estimates using the predictive and retrospective review models

en at this event to see if different levels of medical services should be provided,[5] and an injury surveillance study was undertaken to explore injuries that occur at a mass-gathering event.[7]

Methods

The event organizers have attendance figures readily available for previous years, so a daily crowd size was calculated based on the retrospective (historical) data. Using the historical data, the average crowd attendance was analyzed by individual day based on the average daily attendance from 1995–2001. The average daily total then was applied to the Arbon method. For temperature, the maximal daily temperature as forecast in the previous 24 hours was used, rather than the actual temperature on the day. The performance of the two methods then was compared against the actual number of patients presenting for treatment. A prospective evaluation was undertaken comparing the predicted numbers of patient presentations and ambulance transfers based on the Arbon *et al* Predictive Model (Arbon method) and the retrospective (historical) analysis undertaken by Zeitz *et al* (Zeitz method).[4] In brief, the Arbon method was used to predict medical work for each day of the nine-day event using the web-based calculator, which uses a variety of event profiling information, and is supplemented by an estimate of crowd size for each day (generated from the historical data available). Subsequently, the Zeitz method was used to predict the number of patient presentations for each day of the nine-day event. This method uses the predicted maximum temperature for the day-of-the-week and crowd size. Once the event was staged and the actual numbers of presentations determined, the actual number of presentations was compared to the two predictions for each day.

All predictive calculations using the Arbon method defined the event as crowd-mobile, event-bounded, nonsporting, combined indoor/outdoor venue, and covered day/night with an average daily humidity of 55% (based on the mean values for the previous seven years daily humidity). Due to the reporting nature of the Arbon method, crowd size by day of the event was based on the historical average, from 1995–2001. Then, these data formed the basis for analysis of accuracy for both the Zeitz method and Arbon method.

Prior to the Royal Adelaide Show commencing in August 2002, calculations were undertaken to predict the number of patient presentations and ambulance transfers using the Arbon method and the Zeitz method (based on historical data and predicted daily maximum temperature). The predictions were compared to the data collected during the actual event on patients presenting for treatment and patients transferred to a hospital. These data sets formed the basis for the analysis.

Data processing was undertaken using Microsoft Excel (Microsoft, Redmond, California) and Statistica (Statsoft, Tulsa, Oklahoma). Univariate analysis by Spearman's correlation was used to compare the predicted with the actual data. Deviation from predicted workload was assessed using Student's paired *t*-test. Coefficients of variation were determined for each comparison. Statistical significance was set at a p-value of <0.05.

Results

The expected numbers of patient presentations and patient transfers to a hospital predicted by both methods are presented in Table 1.

Attendance

Data existed on the annual crowd attendance and by-day attendance at the event for seven years (1995–2001). Based on these data, an average value of 616,625 attendances for the nine days was predicted. There was no significant difference in total attendance figures for 2002 compared to the calculations resulting from the historical data. The crowd attendance, based on the mean values for the previous seven years was compared to the attendance on each individual day of the event. This comparison is in Table 2. Predictions, based on historical data by individual day,

Year	Annual Total
1996	14
1997	16
1998	29
1999	28
2000	23
2001	17
2002	48

Table 4—Annual numbers of patients transferred to a hospital

accurately predicted the actual attendance ($r = 0.95$, $p < 0.001$). The maximum variation from the predicted figure for any day was 21% with a median variance over the nine days of 8%.

Daily patient presentations

The day of the week had an important influence on the number of patients presenting for treatment.[4] Use of the Arbon method for prediction does not discriminate by day of the week, but it does vary according to the expected crowd size. This reflects actual practice in terms of resource planning (Table 1).

The number of patients treated on any day varied widely with overall patient presentation rate (PPR) (patients presenting per 1,000 patrons/spectators) of 1.6 (range 0.9–2.5). Generally, there was good correlation between the number of actual and predicted presentations using the Zeitz method ($r = 0.65$, $p = 0.06$, median variance = 7%). Use of the Arbon method did not generate a close correlation with actual number of patient presentations ($r = 0.12$, p = not significant, median variance = 19%), and tended to over-estimate the number of presentations for most days. The Zeitz method predicted the number of patient presentations that did not differ significantly from the numbers actually observed (Table 3). However, use of the Arbon method predicted a number of patient presentations that were significantly different statistically from those observed ($p < 0.04$).

Ambulance transfers

Using the average estimated crowd size by day, the Arbon method estimated three patient transfers to a hospital for each day. The Zeitz method estimated a range of 1–4 transfers. The actual range of ambulance transfers was 3–11. The ambulance transfer rate was particularly high for 2002 in comparison to previous years (Table 4) with the number of patients transported to hospital per 1,000 patrons in attendance (TTHR) = 0.07 and a transport to hospital rate (THR) of 48/622,234. Both methods estimated similar numbers of patients that may require transportation to hospital (Table 5). For 2002, neither method reliably predicted the number of patients that required transportation to a hospital with the results from the use of both methods differing significantly statistically from the observed data ($p < 0.05$).

Day	Actual	Predictive Model	Retrospective Review
1st Friday	4	3	4
1st Saturday	11	3	3
Sunday	6	3	1
Monday	3	3	2
Tuesday	3	3	2
Wednesday	7	3	3
Thursday	4	3	2
2nd Friday	4	3	2
2nd Saturday	5	3	3
Total	**47**	**27**	**22**

Table 5—Comparison of ambulance transfers by day for each model

Discussion

Forecasting the number of patient presentations is necessary to underpin decisions relating to allocation of medical resources at public events. Previous mass-gathering research has focused on analysis of single events and both the Arbon method and the Zeitz method furnish service providers with systems to more accurately estimate probable patient presentations.

Whereas the Arbon method is based on a diverse range of mass-gathering events, the Zeitz method arises from reviews of a specific event. Crowd size, on a daily basis, was readily and accurately predicted using the historical data. However, the need is to be able to predict medical workload at events, and while this is somewhat dependent on crowd size,[2,3] there are other factors.[8]

The predictions made using the Zeitz method not only varied depending on crowd size (and hence day of the week), but also identified differing crowd demographics on different days that had an additional influence on the number of patients. Historical data has shown that medical workload is highest on a mid-week day with half-price admission, even though the largest crowds attend at weekends. The Zeitz method also found maximum daily temperature was another significant influence on patient presentations.

Based on well-documented factors that influence medical work, such as weather (temperature and humidity) and event profile indicators (boundaries, location, mobility of crowd), both models forecast the number of patients presenting on a daily basis. In undertaking this study, the Arbon method was assisted by the retrospective calculation of variance due to different crowd sizes based on the day of the week. The PPR of 1.6 was the same as for previous years. The Zeitz method also had highlighted that if weather was bracketed, different predictions could be made. It is noteworthy that while the Arbon method found humidity, not temperature to be an important determinant of the number of patient presentations; on the other hand, the Zeitz method found temperature to be an important determinant. This is likely to reflect the fact that the Arbon method was based on a much greater variety of events from

varied locations throughout the calendar year, whereas the Zeitz method examined a single event held at the same time every year. Furthermore, while forecasted temperatures usually are available up to one week prior to a scheduled event, a forecast for humidity only rarely is available. As such, it was considered appropriate to use the average humidity for the event for the previous seven years for the Arbon method. It is possible that this assumption may have been a weakness for this study.

Ambulance transfers, for the most part, are quite small in number. The use of both methods forecast smaller numbers of transfers on a daily basis. For unknown reasons, the actual transfer rates to a hospital were particularly high at THR of 48/622,234 (TTHR of 0.07) in comparison to previous years (TTHR of 0.034).[4]

For the first-time, planners for the provision of health care at mass-gathering events have access to methods that can estimate the number of patient presentations. The Arbon method is particularly useful for events where there is no or limited information about previous medical work e.g., one-time, special events. It provides a broad prediction based on the combination of information gathered from a range of events. This prediction has proven to be accurate over the entirety of the event, but is limited in its ability to predict inter-day variability. Retrospective review of data generated from specific events considers the unique and individual variability that can occur from event-to-event and is more accurate for predicting patient presentations when the data are available. More importantly, for multi-day events, it provides incremental information regarding inter-day variability, enabling a more efficient assignment of human and other resources.

Conclusion

The two methods can be considered complementary in more accurately determining medical work during public events. While the methods do not incorporate the level of medical assistance required (i.e., skill levels of medical service), both can be used to adequately and efficiently plan resources for events.

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